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PHYSICS.—*Temperature changes accompanying isentropic, isenergic, and isenkaumic expansion.*[1] LEASON H. ADAMS, Geophysical Laboratory, Carnegie Institution of Washington.

The pressure on a fluid may be changed from its initial value to some final value in several well-recognized ways. The temperature changes accompanying the release of pressure depend on the method by which the pressure is released, and may be calculated from the conventional equations of thermodynamics. It is the object of this communication to note, largely because of the connection with geophysical problems, the changes in temperature of typical fluids when pressure is released according to three principal methods.

These methods are as follows:

(A) *Reversible release of pressure. Isentropic expansion.*—This, the most familiar of the three kinds of expansion, takes place when a fluid (*i.e.*, a gas or a liquid) is expanded, for example in a cylinder with movable piston, without exchange of heat with the surroundings under such conditions that frictional effects are (sensibly) absent and slowly enough so that equilibrium is maintained, *i. e.*, that the external force acting on the piston is (sensibly) equal to the opposing force exerted by the fluid.

Under such conditions the entropy (S) of the fluid remains constant, the process is called *isentropic*, and the relation between temperature and pressure is given by the equatoin:

$$-\left(\frac{\partial T}{\partial p}\right)_s = -\frac{\alpha T}{c_p} \qquad (1)$$

in which T is the absolute thermodynamic temperature, c_p is the specific heat at constant pressure, α is the coefficient of expansion $\left(\frac{\partial v}{\partial T}\right)_p$, v being the volume of unit mass. The first member of

[1] Received October 13, 1922.

the equation is written $-\frac{\partial T}{\partial p}$ for convenience in representing the rise in temperature due to *decrease* of pressure.

(B) *Explosive release of pressure. Isenergic expansion.*—When pressure on a given amount of material is released in such a way that no heat is added to or taken away from the material and no work is done on or by the surroundings, the intrinsic energy (E) of the material remains constant, and the expansion may be termed *isenergic*. This type of expansion may be realized by allowing a gas to expand from one part of a container to another (evacuated) part, or—of more practical interest—by the sudden release of pressure on a liquid contained under high pressure in a bomb, *e. g.*, by a breaking of the walls or by a blowing off of the lid.

The relation between temperature and pressure in isenergic expansion is:

$$-\left(\frac{\partial T}{\partial p}\right)_E = \frac{\beta p - \alpha T}{c_p - \alpha p} \qquad (2)$$

β being the compressibility, namely, $-\left(\frac{\partial v}{\partial p}\right)_T$

(C) *Porous plug release of pressure. Isenkaumic expansion.*—The third variety of expansion occurs when a fluid—as before, insulated thermally from the surroundings—reduces its pressure by streaming through a porous plug or through a throttle of some sort. In this case a certain thermodynamic quantity, represented by the letter H and commonly called heat content, remains constant. The expression, heat content, is sometimes confused with heat capacity and, moreover, the two-word name does not lend itself well to the formation of derivatives. Thus, "isoheatcontentic" would be an awkward term. For these reasons a single-word equivalent of heat content would be desirable, and the word *enkaumy*[2] is here proposed.

In the process just considered the enkaumy remains constant, and for this *isenkaumic* expansion the relation between temperature and pressure is:

$$-\left(\frac{\partial T}{\partial p}\right)_H = \frac{v - \alpha T}{c_p} \qquad (3)$$

[2] Greek, καυμα from καιειν to burn. Cf. obsolete English word, *cauma*, heat. For the suggestion of this root I wish to thank my colleague, Dr. Henry S. Washington.

It is of interest to note that $-\Delta H$, the difference in enkaumy of two states, is the exact equivalent of the heat of combustion, or the heat of reaction, at constant pressure.

The equations given for the three types of adiabatic expansion apply strictly only when the pressure on the substance is purely hydrostatic, *i. e.*, equal in all directions. This limits the rigorous application of such formulas, particularly (2) and (3), to liquids and gases; but if the pressure on a solid be many times the strength of the material, the pressure may be nearly equal in all directions, and the equations may then be used for calculating the piezo-thermal effects in solids. The error involved will naturally be smaller, the larger the pressure. For example, when a metal is extruded through a die by a pressure of many thousands of atmospheres, the rise in temperature can be estimated from equation (3) and the known properties of the metal.

The temperature effects for the three kinds of expansion and for a number of typical substances are shown in the following table.

NUMERICAL VALUE OF TEMPERATURE RISE FOR THE THREE KINDS OF EXPANSION. $-\partial T/\partial p$ IS THE RISE, IN DEGREE CENTIGRADE PER MEGABAR FALL IN PRESSURE

Material	Temp. Deg. C.	Pressure megabars	$\partial T/\partial p$ At. const. S (Isentropic)	At. const. E (Isenergic)	At. const. H (Isenkaumic)
Nitrogen	0	1	−83.4	−0.38	−0.26
Hydrogen	0	1	−79.3	−0.02	+0.03
Water	20	1	−0.0013	−0.0013	+0.023
Water	20	4000	−0.0028	−0.0010	+0.021
Kerosene	20	1	−0.017	−0.017	+0.043
Lead	25	4000	−0.0020	−0.0013	+0.068

In making calculations with equations (1), (2) and (3) it is convenient to take v in cubic centimeters per gram, p in megabars (1 megabar = 0.9869 atmosphere at latitude 40°), and c_p in deci-joules per gram per degree (1 calorie = 41.84 deci-joules). An alternative way is to take p in kilograms per square centimeter, and c_p in kilogram-centimeters per gram per degree.

The values of $\left(\frac{\partial T}{\partial p}\right)_H$ for nitrogen and hydrogen in the above table were not calculated from equation (3), but are the results of direct measurements of this, the Joule-Thomson effect. Likewise it was more convenient to calculate $\left(\frac{\partial T}{\partial p}\right)_E$ for these gases from the relation:

$$-\left(\frac{\partial T}{\partial p}\right)_E = -\frac{\mu c_p + a}{C_v}$$

which holds with sufficient accuracy for gases. In this equation μ

is written for $\left(\frac{\partial T}{\partial p}\right)_H$ and a for $\left(\frac{\partial (pv)}{\partial p}\right)_T$. Values of both μ and a for the more common gases are to be found in the literature.

The kerosene referred to is the ordinary commercial product having a density of about 0.8.

Probably the temperature always falls in isenergic expansion—at least over the range of temperatures and pressures which have hitherto been investigated. This is equivalent to the statement that the internal energy of a substance steadily decreases as the pressure is increased.[3] Isentropic expansion causes a fall in temperature, except in those rare cases where the expansion coefficient is negative, *e. g.*, water below 4° C. For isenkaumic expansion, however, there is no such regularity. At temperatures sufficiently high the temperature of a fluid rises during isenkaumic expansion; at intermediate temperatures it falls; while at still lower temperatures it again rises, except at pressures above a certain limit, under which conditions the change is always a rise.[4] At moderate pressures there are thus two inversion points where $\left(\frac{\partial T}{\partial p}\right)_H$ changes sign. One is somewhere near the ordinary boiling-point, while the other is at a temperature several times the critical temperature.

Since the βp and αp terms in equation (2) are small for liquids except at high pressures $\left(\frac{\partial T}{\partial p}\right)_S$ and $\left(\frac{\partial T}{\partial p}\right)_E$ for ordinary liquids are practically identical at low or moderate pressures. It is hardly necessary to point out that for an ideal gas $\alpha T = \beta p = v$, and hence for an ideal gas the right-hand members of equations (2) and (3) reduce to zero. For ordinary solids and liquids v is much greater than αT; therefore $-\left(\frac{\partial T}{\partial p}\right)_H$ is practically equal to $\frac{v}{C_p}$. Thus, the heating effect when such materials are expanded isenkaumically is nearly equal to the thermal equivalent of the work done ($v\mathrm{d}p$) in forcing the material through the porous plug or throttle—more approximately the total heating effect is the algebraic sum of this thermal equivalent of the net work done on the substance, and of the cooling effect accompanying isentropic expansion, the latter being comparatively small for all solids and liquids. For these materials,

[3] Cf. P. W. Bridgman. Proc. Am. Acad. Sci. **48**: 348. 1912.

[4] Cf. W. McC. Lewis. System of Physical Chemistry, Vol. II, p. 71. London, 1920.

therefore, we may, if we like, regard the rise in temperature during extrusion as being (nearly) that due to the conversion of the work expended on them into heat, this conversion being effected by friction along the walls or by internal friction (viscosity); but for gases, of course, this is not even approximately true.

It is of interest in this connection to note the behavior of antimony when extruded through a small opening. According to Bridgman the extrusion at certain pressures proceeds slowly and regularly, but if the pressure is raised to a certain critical value, the antimony comes out with almost explosive violence and in the form of a long, continuous wire. Now the temperature rise for isenkaumic expansion of antimony is about the same as for lead, namely about 70° per 1000 megabars. Since the pressure was 10,000 megabars or more, the question may well be raised as to whether the antimony, in spite of heat losses, may not have been raised to its melting point at ordinary pressure, namely, 630° C.

PHYSICS.—*Some observations on the transformation of thermal radiant energy into electric current in molybdenite.*[1] W. W. COBLENTZ, Bureau of Standards.

As announced in the Bureau of Standards Tech. News Bulletin, No. 61 of May 11, 1922, during the past year the writer has been searching for a possible relation between (1) an e.m.f. which is observed in isolated spots in certain samples of molybdenite when exposed to thermal radiation but without an impressed e.m.f., and (2) the photo-electrical reaction (which is usually considered a change in resistance) exhibited in these same spots when subjected to an impressed e.m.f. and exposed to thermal radiation.

The materials examined are narrow strips of molybdenite 1 to 6 cm. in length, soldered to copper wires which are connected with a Thomson galvanometer.

Touching the copper-molybdenite junctures with a thin hot wire produces the well known thermal e.m.f. of a heterogeneous circuit. Touching the intervening parts of the crystal with the hot wire produces no e.m.fs.

On the other hand, focusing the short wave-length radiations from a Nernst glower or tungsten-ribbon lamp upon different parts of the

[1] Received September 16, 1922.

crystal, remote from the electrodes, produces, in some samples, local e.m.fs. which differ in magnitude and in polarity.

Exposing a spot, exhibiting a high local e.m.f., to an equal energy spectrum, an electric current is generated which is a function of the intensity and the wave-length of the light stimulus, and of the thickness of the crystal. The maximum effect was produced by wave-lengths extending from 0.6 to 0.8 micron, and no e.m.f. was found for wave-lengths greater than 1 micron.

The spots exhibiting local e.m.fs., caused by thermal radiation do not seem to coincide always with the spots exhibiting the photoelectrical reactions (change in resistance) when there is an impressed e.m.f.; though further investigation may show that this is owing to the fact that the thermal e.m.f. effect is found to be extremely small in comparison with photoelectrical reaction.

The polarity of this newly observed thermal e.m.f. may be photonegative or photopositive, depending upon the wave-length of the thermal radiation stimulus just as was previously observed for the photoelectrical reaction (resistance change) when there is an external e.m.f. It is therefore an interesting question whether the so-called photoelectrical reactions in solids, when subjected to an impressed e.m.f., are an amplification of the e.m.fs. produced by the thermal radiation but without an impressed e.m.f.

PHYSICS.—*A device for recording electric contact using an electron tube generator and a radio-frequency spark.*[1] CHARLES T. ZAHN, Princeton University. (Communicated by S. W. STRATTON.)

It is sometimes desirable to have a convenient means of recording an electric contact of relatively short duration, of the order of one thousandth of a second. For a particular use it was found that various devices which have been used heretofore were either not satisfactory or not convenient. It was suggested that the use of the three-electrode electron tube generator might be successful. The following is a description of some experiments performed at the radio laboratory of the Bureau of Standards with this end in view, and is given here simply to illustrate a new experimental method.

The three-electrode electron tube generator was used as a source of radio-frequency alternating current to produce a radio-frequency

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce. Received September 19, 1922.

spark, by means of the high voltage induced in a coil whose natural frequency is the same as that of the applied field. (This radio frequency was about 300,000 cycles per second.) The *duration* of this spark was controlled by an electric contact within the generator circuit, and registered by letting the spark puncture a moving piece of carbon paper. It was a matter of experiment to see how nearly the spark, with the particular arrangement used, followed the electric contact made and broken in the generator circuit.

The exact arrangement of apparatus which was first used is shown in Fig. 1. It consists of a simple electron tube generator and a rotating chopper K used to make and to break the contact at the filament terminal of the tube and thus to start and to stop the generation of radio-frequency current, respectively. The coil L_3 is a large coil of

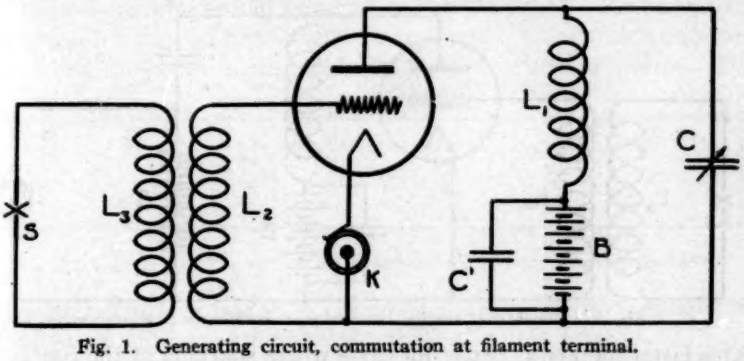

Fig. 1. Generating circuit, commutation at filament terminal.

the type known as "stagger wound" or sometimes as "spider web," and has a natural frequency of such a value that the generator can be tuned to it by means of the condenser C. By means of coupling the coil L_3 with coils L_1 and L_2, which are coupled to each other, and tuning, a radio-frequency voltage is induced in the coil L_3 sufficient to maintain a series of sparks between the coil terminals when they are brought close together as shown in Fig. 1. The duration of this series of sparks is registered in the following manner. The chopper K is divided into alternate equal segments of insulating and conducting material so that the spark exists for equal time intervals separated by time intervals equal to those of the spark duration. A piece of carbon paper in the form of a cylinder is made to rotate about its axis in synchronism with the chopper by having it wrapped around a brass drum which is mechanically coupled to the shaft which rotates the

chopper. One terminal of the coil L_3 is connected to this brass drum and the other terminal in the form of a needle point is fastened within a millimeter's distance from the carbon paper. During the time when the chopper makes contact a spark passes between the needle point and the brass drum through the carbon paper, and while the contact is interrupted no spark passes. Thus the carbon paper is punctured at equal intervals around the cylinder.

The arrangement of apparatus for another method of controlling the radio-frequency current is shown in Fig. 2. Here a resistance R of about 10 ohms, sufficient to prevent the generation of radio-frequency current, is inserted in the oscillating circuit of the tube. The chopper is connected across this resistance. When this resistance is short circuited by the chopper, radio-frequency current is generated.

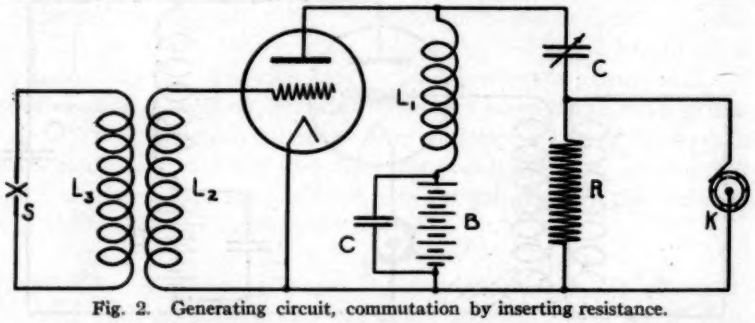

Fig. 2. Generating circuit, commutation by inserting resistance.

This latter method is better for cases where sparking at the contact is objectionable, for in the former method the chopper interrupts the plate current.

The following experimental details may be of interest. Several types of coil for L_3 and several types of electron tubes were tried. The stagger-wound coil gave the best results as regards power considerations. At first a General Electric Type P pliotron tube rated at 250 watts was used at rated plate voltages. This gave much more power than was necessary, so several other combinations were tried, to see whether enough power could be generated using 220 volts on the plate of the tube. With this latter plate voltage neither a General Electric Type P 250-watt tube, nor two General Electric Type U 50-watt tubes, nor four Western Electric Type E 5-watt tubes gave sufficient power: therefore, it was decided to use a single Type U tube with 500 volts on the plate.

The following is an application of this electron tube recorder. In the Automotive Power Plant Section of the Bureau of Standards a method has been devised to record automatically the pressure-volume curve for a gas engine cycle.[2] A mechanical arrangement was worked out which for any given pressure makes an electric contact continuously during the time of the cycle when the pressure in the engine cylinder is greater than or equal to this given pressure. Thus the pressure in the engine cylinder is equal to this given pressure at times corresponding to the makes and the breaks of electric contact, and these times correspond to points on the curve whose ordinates are equal to the given pressure. It was attempted to register this time of contact by low-frequency sparks. A drum covered with carbon paper was to be rotated in synchronism with the engine, and for any given pressure the time of sparking would be registered on the paper. For the different pressures parallel lines would be registered, all of which together would give the pressure diagram in the form of an area of sparks. The

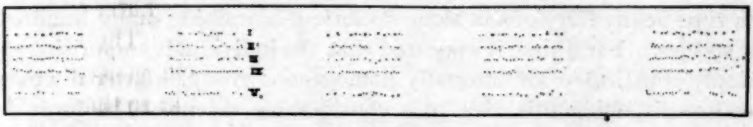

Fig. 3. Carbon paper record of spark passing when chopper contact is closed.

difficulties found in trying to use low-frequency methods should be obviated by applying the device described in this paper.

The time of duration of the radio-frequency spark in the experiments described in the beginning of this paper is actually registered as a series of dots about a millimeter apart and the equality of time interval of contact and open circuit is registered on the carbon paper to an accuracy corresponding approximately to the distance between the dots just mentioned. It is believed that if the length of spark gap is reduced, the accuracy of the production of equal intervals can be considerably increased. The fact that a series of dots is obtained instead of a continuous cut in the paper is probably due to differences in conductivity of the paper at different points or to an effect on the tube generator due to the passing of the spark from the coil L_3. The frequency of these dots is about one fiftieth that of the radio-frequency.

[2] H. C. Dickinson and F. B. Newell, "A High-Speed Engine Pressure Indicator of the Balanced Diaphragm Type," Report No. 107 of the National Advisory Committee for Aeronautics, Washington, 1921. Government Printing Office.

The accompanying Fig. 3 is a reproduction of five series of these dots, each series corresponding to a different position of the needle. The first four series were taken with different speeds of rotation of the drum the maximum linear speed of the carbon paper being about 500 cm. per second; the last series was registered with the direction of rotation reversed. This diagram shows that there could not have been a time lag in starting or stopping the generator corresponding to more than 2 millimeters on the carbon paper, *i.e.*, there could not have been a lag of more than 1/2500 second.

The writer is indebted to Mr. F. B. Newell for the loan of special apparatus used in performing these experiments and to Mr. L. E. Whittemore for valuable suggestions in the work.

ZOOLOGY.—*A new species of* Nygolaimus, *an outstanding genus of the Dorylaimidae.*[1] N. A. COBB, United States Department of Agriculture.

The *Dorylaimidae* constitute one of the largest families of nemas, its type genus *Dorylaimus* alone doubtless containing many hundreds of species. For a time it appeared that the individuals comprising the family constituted an unusually homogenous group. Later discoveries are dispelling this idea to a considerable extent. The form described herein belongs to one of the more outstanding genera, *Nygolaimus*. It is too early to speculate very profitably as to the relationships of the *Dorylaimidae* to other nemic families, but the structure of *Nygolaimus* stimulates hypotheses.

Recently the *Dorylaimidae* have come into consideration as an economic factor in the soil; additional information with regard to their structure and habits is therefore much to be desired, and this is one of the main reasons for the publication of the following note.

Nygolaimus denticulatus n. sp. $\frac{1.8 \quad 5.4 \quad 22. \quad\quad Y. \quad 98.8}{1.1 \quad 1.3 \quad 1.6 \quad\quad 1.6 \quad 1.4}$ 4.3 mm. The thick layers of the transparent, colorless, naked cuticle, measuring five microns through near the head and fifteen microns on the tail, are traversed by very fine transverse striae, difficult of resolution, which are not altered on the lateral fields. It is barely possible with the highest powers to resolve these striae into rows of excessively faint dots. The striae are near the surface of the cuticle, probably in the thin outer layer, which measures about three-fourths of a micron in thickness. The contour of the body is plain. There are no dermal

[1] Received October 19, 1922.

appendages. On each lateral field, extending from near the head to the tail, there is a *double series of sublateral pores* not forming exact lines but arranged slightly irregularly, the distance between them averaging somewhat less than the diameter of the body. This distance, however, varies somewhat and is perhaps a little greater anteriorly than posteriorly, so that there are toward one hundred fifty pores on each lateral field. Each of these organs at its surface presents a slight but relatively broad depression in the cuticle. From the center of this depression there extends inward at right angles to the surface of the body a narrow tube, three-fourths of a micron in diameter, which extends to the lateral chord, where it rather suddenly expands and connects with a broadly *saccate unicellular gland* located in the tissue of the chord. These glands and ducts are a prominent feature of the anatomy of the living nema and strike the observer at first glance, especially if the nema be viewed dorso-ventrally. The neck, which is cylindroid posteriorly and more or less conoid anteriorly, becomes convex-conoid at the continuous, subtruncate to truncate, head. The mouth opening is central, depressed, and relatively conspicuous. It is surrounded by six confluent, subspherical, well-developed lips, each supplied with two minute papillae which do not interfere with the rounded contour of the lip; one of them is outward pointing and the other also barely outward pointing. This latter, the anterior one, is located near the border of the lip region; the posterior one, somewhat farther back and on the outer surface of the lip region. It seems possible that the lips, or some of them, present additional very faint papillae. The somewhat hexagonal lip region, which is nine microns high and

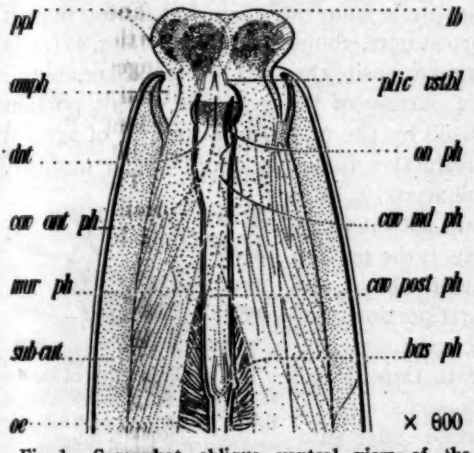

Fig. 1. Somewhat oblique ventral view of the head end of *Nygolaimus denticulatus n.sp.* *ppl*, anterior and posterior labial papillae; *amph*, amphid; *dnt*, denticles lining the wall of the pharynx; *cav ant ph*, *cav md ph*, *cav post ph*, anterior, median and posterior segments of the pharynx; *mur ph*, wall of the pharynx; *sub-cut*, subcuticle; *oe*, oesophagus; *lb*, lip region; *on ph*, onchium; *bas ph*, base of the pharynx; *plic vstb*, folds in the vestibule.

eighteen microns wide, is distinctly set off by constriction; and especially laterally, on account of the *large and conspicuous amphids*, located just at the base of the lip region. The pharynx is entered through a vestibule, more or less hexagonal when closed, about nine microns long and at its narrowest part, when the lips are at rest, normally not over one micron wide. The pharynx, like other parts of the anatomy, is distinctly dorylaimoid, but the very small *left ventrally submedian tooth-like onchium*, only six microns long and one and one-half microns wide at the base, instead of being tubular, as in *Dorylaimus*, is closed. *The food does not pass through it*, but to one side. Speaking broadly the pharynx is of double structure,—the anterior portion being somewhat napiform or fusiform, and the posterior more or less tubular or prismoid. To go into particulars, the pharynx may be said to be divided into four parts, arranged tandem, reached through a narrow vestibule from the somewhat flaring mouth opening. Part one, the shortest part, about five microns long, extends from the vestibule to the region opposite the apex of the solid onchium, and might be regarded as a portion of the vestibule. This portion of the pharynx is characterized by the presence in its wall of several short longitudinal ribs or refractive folds, no doubt six in number. The second portion of the pharynx, a little longer than the preceding and with it forming a broadly fusiform cavity, is the portion of the pharynx containing the onchium, and is lined throughout the greater portion of its length with a *multitude of excessively fine denticles*, apparently similar to those found in the pharynx of some mononchs, and, as there, slightly larger and more regular anteriorly. The third portion, eleven microns long, is the anterior third of the tubular part of the pharynx, while the fourth and longest portion, twenty microns long, is the posterior two-thirds of that tube. Thus the entire pharynx is *nearly sixty microns long*. The distinction between parts three and four is not very marked; it manifests itself in the varying refractivity of the lining of the two parts, and also in the tendency of the posterior part to be more prismoid or cylindroid, while the anterior third tapers slightly from front to back. The thickness of the various parts of the highly refractive walls of the pharynx is somewhat variable,—from a

Fig. 2. Front view of the lip region of *Nygolaimus denticulatus n.sp.* *ppl ant, ppl post*, anterior and posterior labial papillae; *ph*, pharynx; *amph*, amphid; *lob vnt subm, lob dsl subm*, ventrally and dorsally submedian lobes of the lip region; *on*, onchium.

half to one micron thick. The width of the main, that is, posterior, portion of the cavity of the pharynx is about four microns. The *slender slightly arcuate onchium* is one-third as long as the lip region is wide and when at rest reaches one-third the distance from its base to the anterior border of the head. It is a left ventrally submedian organ, and may almost be said to be set *in a pharyngeal niche of its own*. Not only is it slightly arcuate but the tendency is for its apex to be swung outward a little when at rest. It tapers from its base to its acute anterior extremity and at its widest part is about one-fourth as wide as the adjacent cuticle is thick. That portion of the compound pharnyx behind the base of the onchium is about one and one-half times as long as the part in front of it, vestibule included. It is the *posterior two-thirds of the fusiform widest portion of the pharynx which is lined with the above-mentioned denticles*. The large amphids, like the onchium, are very much like those of *N. pachydermatus*, and are very conspicuous, and externally somewhat *escutcheon shaped;* they have their front borders removed from the anterior extremity of the nema a distance about one-third as great as the corresponding diameter of the head. They are about three-fifths as wide as the corresponding part of the head and nearly as long as wide. There are no eyespots. The oesophagus, which is dorylaimoid, enlarges somewhat gradually near the middle; the two parts of the oesophagus are not very clearly set off from each other. Behind the pharynx the oesophagus is about one-third, at the nerve ring about one-fourth, and finally about one-half as wide as the corresponding portion of the neck. The lining of the oesophagus is a very distinct feature throughout its length; anteriorly it is tubular and highly refractive and about one-fourth as wide as the oesophagus; posteriorly it is more distinctly triquetrous and somewhat wider—again about one-fourth as wide as the corresponding portion of the oesophagus. The musculature of the oesophagus is rather coarse and colorless. It is not yet known positively whether there are any glands in the tissue of the oesophagus—but it is almost certain that they are present. The conoid cardia is about one-third as wide as the base of the neck. There are no valves in the oesophagus. The rather opaque thick-walled intestine, which presents a faint, very slightly zigzag lumen, becomes at once one-half as wide as the body, and is separated from the oesophagus by a collum about one-third as wide as the base of the neck. It is composed of cells of such a size that about six are presented in each cross section. There is a *distinct pre-rectum* about five times as long as

the corresponding width of the body. It is set off from the intestine not only by being slightly less in diameter but by being more nearly colorless; the intestine itself is yellowish on account of the presence in its cells of certain exceedingly fine yellowish granules. The rectum is readily seen to lead inward and forward from the depressed anus a distance about equal to the anal body diameter. The anus is a transverse slit two-fifths as wide as the corresponding portion of the body. The fine granules of rather variable size which are numerous in the cells of the intestine are *some of them yellowish in color* and taken altogether so arranged as to give rise to a faint tessellated effect. The largest of them are not much over one micron across. The tail is nearly hemispherical. There is no spinneret and there are no caudal setae. Extending backward and outward from the conoid protoplasmic "core" of the tail there are ten to twelve innervations, which are much less clearly visible than are the two tubes leading outward and backward from the two lateral glands located in the tail,—the final members of the lateral series already mentioned. Similar innervations occur toward the head end of the nema and probably to a less extent throughout the body. The cuticle on the tail is very much thicker than elsewhere (15 microns) and is characterized by the presence in it of longitudinal markings which indicate that it is probably finely laminated. The lateral chords, about one-sixth as wide as the body, are deep, about as thick as the body wall—and are coarsely granular. Their cells are made up largely of subspherical granules closely packed together and of such a size that the largest, some four microns across, are about one-twentieth as wide as the body. Among these granules are scattered others, ellipsoidal, measuring up to one micron, and characterized by blackening in Flemming's solution. The nerve ring, which surrounds the oesophagus somewhat squarely, is accompanied by numerous rather obscure nerve cells. Nothing is known concerning the renette. Nothing is known concerning the sexual organs.

Habitat: Found in soil collected by Prof. J. R. Christie at Falls Church, Va., August 29, 1922. Only one young specimen seen. Examined and measured alive in water, and afterwards fixed in Flemming's solution and examined in glycerine.

Nygolaimus is manifestly related to *Dorylaimus*. It undoubtedly belongs to the *Dorylaimidae*, although it may possibly be regarded as a "transition form." Some features of the pharynx remind one strongly of *Mononchus*. The new onchia are sometimes prepared some dis-

tance behind the pharynx, as in *Dorylaimus*. *N. denticulatus* appears to be closely related to *N. pachydermatus*, in which quite possibly dermal pores may have been overlooked.

The mouth structures of *Nygolaimi* appear to harmonize with the supposition that the lip region can be expanded and the lips everted. Otherwise it is rather difficult to understand how the onchium can be efficiently used. The denticles are in relatively about the same position as in *Mononchus*, subgenus *Mylonchulus*, but not in two distinct patches. It seems quite apparent that the vestibule, when closed, is disposed in folds which would admit of its opening out in accordance with the above supposition. The Nygolaims are carnivorous.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

BOTANICAL SOCIETY

156TH MEETING

The 156th meeting of the Botanical Society of Washington was held at the Cosmos Club, on January 3, 1922, with about 75 members and guests present, and President SAFFORD in the chair. Messrs. ERNST F. ARTSCHWAGER, ARTHUR C. DILLMAN, Dr. CHAS. DRECHSLER, Dr. ARTHUR S. RHOADS, ERNST S. SCHULTZ, VICTOR F. TAPKE, and W. H. TISDALE, all of the Bureau of Plant Industry, were elected members of the Society.

Brief notes and reviews of literature.—P. L. RICKER stated that the letter from Dr. HENRY MUHLENBERG, written in 1809, and containing a list of the flora of the District of Columbia had already been purchased by Mr. W. L. MCATEE. W. W. DIEHL spoke of the desirability of making of a list of the fungus flora of the District. Mr. RICKER added that a tentative list of the mycological flora of the District was now being prepared.

Regular program:

L. R. JONES: *Predisposition and resistance to disease in plants.*

Plant pathology is now in a transition period. For some time we have been talking of disease resistance without getting much nearer to the fundamentals underlying this resistance. Such questions must be answered as the particular relation of a particular parasite to a plant, the relation of environment to resistance, etc.

Much of the work of pathologists has been and still is the search for resistant strains or varieties of plants to certain diseases. This is a work which the geneticist and horticulturist can do far better than the plant pathologist. The latter's particular field is not to search for resistant strains, much as this is worth while, but to search for causes of resistance. This involves a study of cell pathology, the study of a single parasite and of single cells of the host plant. Only a beginning has been made on this fundamental work.

Symposium on plant breeding for disease resistance.

W. J. HUMPHREY, *Cereal crops.*—In the cereal crops some diseases were transmitted with the seed as in the case of the smuts. Some measure of success had been achieved with seed treatment, both with the use of chemicals and the hot water treatment. It is not enough to develop a disease-resistant grain, for some of the grains developed by cross breeding, while highly resistant to certain diseases, lacked in milling qualities or in yield. The aim of the plant pathologist and the plant breeder was to secure not only disease-resistant varieties of grain, but to secure grain of good yield and quality.

W. W. GILBERT, *Cotton, truck and forage plants.*—A double gain was obtained by securing disease resistant plants; a gain in the product itself and a gain in the greater utilization of the land. There are certain requisites for selection and hybridization, to get disease resistant varieties or species. 1. The land must be naturally or artificially infected. 2. Work must be carried on in an environment suitable for the disease. 3. The use of a large number of varieties or strains.

The question arises, Is disease resistance in plants permanent? The failure of the cotton farmer to continue selection in the case of wilt-resistant cotton, shows how this resistance to disease becomes lessened. Resistance to disease is specific. One variety or one plant may be resistant to one disease, but that does not signify a resistance to all other diseases.

MERTON B. WAITE, *Fruits.*—Much of the early work in breeding for disease resistance in plants was carried on by natural selection, the survival of the fittest, as well as consciously by orchardists. The gardener and orchardist have done as much as the plant breeder or plant pathologist along this line. A number of projects were being worked in the Bureau of Plant Industry, including Dr. Swingle's work of breeding for resistance to citrus canker. The breeding of resistant stocks was emphasized as being important.

P. L. RICKER, *Grasses.*—New grasses are being introduced into this country from various foreign countries. Some of these are found to be subject to various diseases in their native country, as well as in this country. One of the biggest problems is in connection with lawn grasses on golf links, which suffered from so-called sun scald, which was found to be a Rhizoctonia. Strains of grasses which were resistant to this disease in one year, were propagated vegetatively and were fairly immune for a couple of years, but in the third year were wiped out completely.

ROY G. PIERCE, *Recording Secretary.*